Property Prices and Urban Forest Amenities

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Quantitative information on residents' valuations attached to urban forests is needed for assessing urban land-use. The aim of this study is to value implicitly non-priced urban forest amenities by comparing dwelling prices and specific amounts of amenities associated with dwelling units. The empirical study is based on data from the sales of terraced houses in the district of Salo in Finland. According to the estimation results a one kilometer increase in the distance to the nearest forested area leads to an average 5.9 percent decrease in the market price of the dwelling. Dwellings with a view onto forests are on average 4.9 percent more expensive than dwellings with otherwise similar characteristics. © 2000 Academic Press

Key Words: amenity benefits; hedonic price method (HPM); dwelling prices; town planning; urban forests.

1. INTRODUCTION

At the present time in Europe, there is growing and wide-ranging demand for green areas, as a result of growth in populations, increased leisure-time, and rising environmental awareness [5, 36]. The quality of the urban environment is increasingly recognized as a key ingredient in the economic regeneration of European cities [45]. However, at the same time, the major trends are cuts in the budgets for green areas and increased pressures caused by urban development and expansion (cf. [21, 36]). Although, there is no precise knowledge about the role played by green spaces in the quality of urban life, the benefits of urban forests are recognized to be many (cf. [19, 31]). They include amenities that are aesthetic, ecological, and economic in nature, as well as those that have a physical or psychological effect on human health, such as pollution control, noise abatement, and the provision of recreational opportunities.

The cost of supplying urban forests can be calculated in a relatively straightforward way, but the benefits are more difficult to estimate. Most urban forest benefits do not have a market price. Therefore they are difficult to include in assessment procedures for the various land-use alternatives. The planning and maintenance of green spaces have seldom received enough attention in urban

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planning and decision-making, with the consequence that quantitative information on the benefits and residents' valuations is needed.

Nordic towns offer good facilities for outdoor recreation and close contact with nature, especially from the general perspective of other Western countries. Trees and forests, as a dominant element of the vegetation, form an essential part of the visual image of a typical Nordic town. Several recreational studies report that participation in outdoor activities is high in all of the Nordic countries, and urban forests play a key environmental role in their popularity (cf. [13, 18, 44]). A particular feature of the green areas in Finland is their natural state: most green spaces are formed from preserved areas of the natural landscape, often in the form of forest vegetation.

At present, in Finland there is no legal requirement to assess the value of the externalities of urban land use, so that, for example, the environmental impact assessment (EIA) procedure required in city planning does not include monetary valuation [24]. However, monetary valuation of the urban forest amenities would be a way of concretizing and measuring commensurately the benefits of residents. The resultant use of the benefit estimates in decision-making would affect several different ways. At a minimum level they might stimulate public awareness of potential values lost in the vanishing of green spaces. At a more ambitious level, their advantage lies in their ability to influence or identify decisions through cost-benefit analysis at project level (e.g., [22]). The latter level may be most appropriate in the case of urban forests, since local conditions vary between cities and towns. Comparing the urban forest benefits with the provision and management costs of the areas could serve as a tool in the formulation of appropriate urban land-use policy. The estimates would also help in justifying, for instance, the improvement of degraded environments.

One possibility for measuring urban forest amenities in monetary terms is to examine how much people are paying for such benefits in their housing. The hedonic price method (HPM) estimates the value of environmental benefits from the prices of related market transactions. The most common application of the HPM is in the housing market. The selling price of a dwelling reflects characteristics of the dwelling such as the number of rooms, age of building, size of garden, etc. Furthermore, the selling price also reflects locational and environmental features such as proximity to shops, schools, the view onto or access to a wooded park or watercourse, etc. (cf. [39, 47]). Therefore, if a household wishes to enjoy a view onto a forest or a park or to have easy access to wooded recreation areas, it will buy this type of house and pay a premium for it. The method is usually termed a *revealed preference* method in order to distinguish it from the *stated preference* methods such as contingent valuation (CVM), which is based on intended rather than actual behavior.

A hedonic price function can be estimated from data concerning the prices and attributes of housing. There are, however, several issues involved in conducting a comprehensive HPM study, which have resulted in an abundant literature on the subject (e.g., [9, 39, 47]). The analysis requires large data sets, which are laborious to collect. In addition, empirical applications should address some major problems such as the functional form of hedonic equation and multicollinearity among the explanatory variables.

Thus far, quantitative research regarding urban green spaces in Europe has been limited [5]. In Europe about 200 studies now exist dealing with the valuation of

environmental goods, mostly applications of contingent valuation and travel cost methods, and examples of urban forest studies are rare [35]. Some HP studies were made in the 1970s and 1980s both in the USA and Europe [1, 7, 32, 33, 34], but there are only a few examples of contemporary applications of hedonic price method. In Finland Tyrväinen [49] conducted a HPM study in which the diminishing distance to a forested recreation area, as well as the increasing relative amount of green spaces, had a positive influence on house prices. However, the effect of forested parks on apartment prices remained unclear owing to the abundant supply of urban forests. In consequence, the first condition for capitalization, i.e., adequate variation within the variable, was not fulfilled [46]. Thus, additional research under different conditions was necessary.

The purpose of this study is (1) to search for variables suitable for describing close home forest benefits, and (2) to estimate the monetary value of urban forest benefits reflected in dwelling prices. This paper therefore presents the results of an empirical study conducted in the district of Salo in southwest Finland.

2. URBAN FOREST BENEFITS AND HEDONIC MODELS

In valuing urban forests by means of hedonic price method one of the main problems in empirical applications is that the amenities are difficult to define and measure. In most empirical studies the variables measuring urban forest amenities are either missing or approximative (cf. [23, 51, 52, 53]). Theoretically the benefits associated with urban forests can be derived from urban forest functions [31, 48]. In practice, a good starting point is to imagine how residents perceive urban forests and receive the associated benefits from the perspective of their homes and also from the perspective of the surrounding environment. Recreation possibilities and aesthetic enjoyment are probably the greatest benefits of urban forests. Furthermore, wooded green spaces also contribute to clean air and tranquillity in a built-up environment.

The property value technique consists, theoretically speaking, of two stages (cf. [8, 9, 39, 40]). At the first stage, implicit prices for different housing characteristics are estimated. Here, variation in selling prices of dwellings is explained by the characteristics of housing. One can use these implicit prices directly to evaluate the benefits or losses arising from marginal changes in the supply of environmental goods. This procedure will apply when the environmental change affects only a restricted area and a small number of people. In this case, the prices of dwellings affected will adjust to the level of dwellings with similar characteristics, but the hedonic equation will remain unchanged. If dwellings are owner-occupied, the environmental improvement (degradation) will provide a capital gain (loss) for those living in the area [39].

The assumption of marginal changes applies in the majority of cases involving urban forests: where green spaces are converted into another use or new areas are established, the spatial impact on dwelling prices in the housing area will be restricted. The main losses or received benefits will be experienced by nearby inhabitants, while the impact diminishes the farther away residents are located. In consequence, the direct use of implicit prices in valuation using the hedonic model is justified.

In contrast, the use of price estimates is more problematic if the change in question covers the whole urban area or a large part of it. Here, a second stage of analysis is required, where information about implicit prices and data concerning environmental quality are combined to identify the inverse demand functions of characteristics (cf. [16, 39]). Owing to the strict requirements of the data and the econometric problems connected with the second stage, most empirical valuation studies have used only the first-step hedonic regression model [29, 30, 52].

Several econometric issues and problems arise in the estimation of the hedonic models. For example, the functional form of the hedonic price equation cannot be specified purely on theoretical grounds. In consequence, the form of the equation must be determined empirically within the housing market [15, 39, 40]. The hedonic price function is typically nonlinear, since it is a joint envelope function of a family consisting of both buyers value and sellers offer functions.

In an influential article Halvorsen and Pollakowski [15] allowed the data to determine the most appropriate functional form for hedonic price equation. They used the following quadratic Box–Cox functional form

$$P^{(\theta)} = \alpha_0 + \sum_{i=1}^{m} \alpha_i Z_i^{(\lambda)} + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \gamma_{ij} Z_i^{(\lambda)} Z_j^{(\lambda)}, \tag{1}$$

where P is the price of dwelling, the Z_i are characteristics attached to housing, and $\gamma_{ij} = \gamma_{ji}$. $P^{(\theta)}$ and $Z_i^{(\lambda)}$ are Box–Cox transformations

$$P^{(\theta)} = \begin{cases} \dfrac{P^\theta - 1}{\theta} & \text{if } \theta \neq 0, \\ \ln P & \text{if } \theta = 0, \end{cases} \quad \text{and} \quad Z_i^{(\lambda)} = \begin{cases} \dfrac{Z_i^\lambda - 1}{\lambda} & \text{if } \lambda \neq 0, \\ \ln Z_i & \text{if } \lambda = 0. \end{cases}$$

Special cases of the quadratic Box–Cox (1) include log-linear, linear, and semilog, among many others. To test whether a particular functional form is appropriate, the restrictions corresponding to that functional form may be tested using the asymptotic likelihood ratio test statistic [10, 15].

The approach proposed by Halvorsen and Pollakowski [15] has also received criticism [4, 6, 37, 39]. Cassel and Mendelsohn [4], for example, noted that (i) the best fitting criterion does not necessarily lead to more accurate estimates of characteristic prices; (ii) the functional form may be inappropriate for predictions; and (iii) the transformations result in complex estimates of slopes and elasticities which are often too strenuous to be used correctly in policy analysis. Furthermore, also Box and Cox [3] warned against the use of the transformation when the transformed dependent variable is of primary interest, since any nonlinear transformation of the dependent variable will introduce bias. Furthermore, the more parameters there are in the model, the larger will be the variance around each parameter and the more the precision of each parameter will be reduced.

Indeed, it seems that the use of the flexible functional form may significantly complicate the interpretation of the results [39]. Because of the problems described above, the usual practice has often been simply to assume some arbitrary functional form, such as linear, log-linear or, most frequently, semilog [2, 15]. Cropper et al. [6] proposed that the linear Box–Cox functional form may be the most useful.

Palmquist [39] suggests that the environmental variable could be transformed by a separate transformation parameter in the estimation of the hedonic model.

Furthermore, the relationship between the dwelling price and an independent variable is not necessarily monotonic. According to Laakso [23], non-monotonic relationships are typical of variables such as a distance from the dwelling to local externality. He suggested that continuous independent variables could be transformed into dummy variables if data set is large. Another possibility to study the shape of the relationship between variables is to estimate spline functions [23, 28].

Besides the functional form of the hedonic price equation, also other econometric problems require special attention. One of these issues is the choice of appropriate variables in the models. Theoretically, the price equation should include all the housing characteristics included in the utility functions of households. The choice of variables in empirical studies has restrictions such as the availability of data and multicollinearity. According to Laakso [23], the number and quality of explanatory variables vary considerably between the different studies. In Laakso's review of 18 hedonic price studies the number of explanatory variables in the models varied from 3 [26] to 30 [38].

In hedonic models some explanatory variables are often multicollinear. In consequence, estimating accurate and stable regression coefficients may be difficult. One solution to the problem is to omit a highly collinear variable from the model, provided this does not lead to serious specification bias. For example, Ohlsfeldt [37] implies that restricting the number of variables may also make the interpretation of results easier. Of course, it is also possible to use some other multivariate statistical method than regression analysis [39].

Moreover, according to Goodman [11], the price structures of hedonic models are not as stable as one would hope: estimates from market to market, or from year to year, may differ significantly. In empirical work, aggregating the data from different time periods to obtain enough observations is often necessary. This is, however, questionable if the housing market has received significant shocks over the time period [39]. Hence, temporal stability of estimated parameters has to be studied when aggregating data.

Goodman [11] also contemplates the possibility of spatial autocorrelation. The error terms may be spatially correlated if some relevant variable, typically local externality, is excluded from the regression model. The second form of spatial autocorrelation is more complicated. It may occur if positive error terms in the sale of houses at one location may noticeably influence sales prices at nearby locations, and less so at more distant locations.

3. DATA

The empirical study was conducted in the district of Salo, which is located 110 kilometers to the northwest of Helsinki. The area was chosen because there were enough housing market transactions during the period of study and also a sufficient variation within the environmental quality. The district of Salo consists of two municipalities, Salo and Halikko. Salo is a town with 23 000 inhabitants (1996) and the municipality of Halikko (9000 inhabitants) is located on the northern border of the town of Salo itself. Halikko is an integral part of the housing market in the region as many people who live in Halikko work in Salo. The biggest employer in

the region is the Nokia Mobile Phones company, which has a production plant in Salo.

Salo itself is an old commercial center within a wide river valley. The main features in the landscape are open fields and forested eskers between the fields. The river Salo runs through the town center and both housing and industry are concentrated along the river. The buildings in the town center are typically not higher than three stories. In most of the housing areas detached houses or terraced houses predominate. Therefore, the general profile of the town is flat. The town of Salo owns approximately 1100 hectares of forest, the majority of which (74 percent), is found outside the area included in the town plan. The green areas near the town center are few and are found along the riverbanks. Most of the forested areas are found in the urban fringe located on hills which start abruptly from the valley. Housing has expanded into these hill areas only in recent decades [43].

The relative number of green areas in Salo has substantially increased over the last decade. In 1986 the green areas represented around 10 percent (190 ha), and 10 years later 17 percent (356 ha) of the planned town area. In 1996, 81 percent of the green areas were forested and 19 percent were constructed parks or shelter-belts [41, 42]. The increase in green areas has been brought about by land acquisition and town planning as well as by the active construction of parks.

An inventory of the urban forest areas in the municipalities was made using the town plans and black and white aerial photographs from year 1987 on a scale of 1 : 5000, which were available from the Geographical Data Center of the National Land Survey of Finland in Helsinki. The minimum size classified as a wooded green space was 0.3 hectares. Neither of the municipalities has urban forest management plans and so detailed information concerning the urban forests was not available. Overall, the urban forests in the district of Salo are quite fragmented and different in respect of both tree species and age-class distribution. Most areas are pine-dominated, but also species such as oak, linden, maple, and hazelnut are frequent.

The dwelling sales sample was collected from owner-occupied terraced house sales in Salo and Halikko. Unencumbered selling prices and basic structural data concerning the characteristics of dwellings have been collected from stamp duty record files charged on housing share transactions. Thus, the data consists of all apartment sales in terraced housing over 3 years in the mid-1980s. The number of housing share transactions in the final sample is 590. Seventy-two observations had to be ignored because information concerning the view from the windows of the dwellings concerned could not be determined precisely in the field investigation. Furthermore, another 17 entries were rejected as the selling price was distinctively lower than the general price level in the housing market.

The data collection was restricted to terraced houses. This type of housing was chosen because the characteristics of such housing vary less than those of detached houses or blocks of flats. The sample included only dwellings which had a maximum of five rooms. Because price fluctuations have been strong in the Finnish housing market since 1987 due to liberalization of financial markets and an increase in interest rates, the data was collected from the reasonably stable period of 1984–1986. The data from different time periods has been combined by converting the nominal selling prices to the 1983 price level using price index for terraced housing in southern Finland (for towns outside the Helsinki area). The

base year of the index is 1983, and the index is produced quarterly by Statistics Finland.

The explanatory variables and their expected signs are presented in Table I. Four different variables measuring urban forest amenities were used with respect to each dwelling. These environmental variables were chosen according to the theory of urban forest benefits and the results of the previous study [31, 48, 49].

(i) **The distance to the nearest wooded recreational area** measures mainly the recreational opportunities in the housing area, although these large forests also have protective and aesthetic functions. In the mid-1980s only two housing areas in Salo had a wooded recreational area with facilities such as skiing and jogging trails. The distance to either of those areas has been measured along the streets, cycle paths or pavements.

(ii) **The direct distance to the nearest forested area** (i.e., forest park) was measured from each terraced house to the edge of the forested area. These forested areas were small, ranging from 0.3 hectares to several hectares, or narrow strips of forest land within the housing district. They are important for screening and pollution control, and have psychological effects with regard to noise abatement and improvement of the urban landscape.

(iii) **The relative amount of forested areas in the housing district** mainly describes the amount of space (construction density) in the housing area, and to a certain extent the general visual landscape in the particular area. In addition, this variable encapsulate partly the technical benefits that urban forests provide (i.e., noise and pollution control). The amount of forested areas was measured on a map of the town by means of a planimeter.

TABLE I

The Explanatory Variables and Their Expected Effects on Sales Price

Explanatory variable	Expected sign*	Explanatory variable	Expected sign*
Floor area of the dwelling	+	Distance to the center of Salo	−
Number of rooms	+	Distance to the Nokia factory	−
Kitchenette = 0, Kitchen = 1	+	Distance to the local shopping center	−
Internal sauna, 0 = no, 1 = yes	+	Distance to the nearest school	−
Roof type, 0 = flat roof, 1 = ridge roof	+	Distance to the indoor swimming pool	−
Brick house, 0 = no, 1 = yes	?	Distance to the nearest wooded recreation area	−
Age of the building	−	Direct distance to the nearest forested area	−
Yard size (lot size divided by number of dwellings in the housing company)	+	Relative amount of forested areas in housing district	+
Municipality, 0 = Salo, 1 = Halikko	?	View of forest, 0 = no, 1 = yes	+
Low status housing area, i.e. Ollikkala 1, 0 = no, 1 = yes	−	View of park, 0 = no, 1 = yes	+

* + increasing/− reducing effect on the selling price. ? indicates an a priori undetermined sign.

(iv)   **The view from the dwelling window** was classified into five categories: (1) the view over construction areas, (2) the forest view, (3) the view onto a constructed park, (4) distant views (e.g., a view overlooking a field), and (5) other (i.e., a view consisting of various features from the previous classes). The view belonged to a particular class if more than 50 percent of the direct view from the window belonged to the specific class.

All distances, e.g., distances from the dwellings to the town center (Salo Market Square), were measured on maps of the town (1 : 10 000 scale) by means of a mapmeter, with an estimated accuracy to the closest 100 meters. The only exception was made in the case of distances to the nearest forested areas, which were measured in the field to the closest 10 meters if there was a view onto forest from the dwelling concerned.

Information on the status of housing areas was obtained by telephone inquiry from local real estate agents. The Ollikkala housing district was distinguished from others as a low status area. Most of Ollikkala was built in the 1970s, and the proportion of blocks of flats is larger than in the other housing districts. The average price of each type of dwelling was clearly lower there than elsewhere. Information about public and private services for 1985–1986 was obtained from the Department of City Planning and the Department of Park Services.

Although water is usually an appreciated feature in the housing area, no separate variables measuring such benefits were included in the model. The main recreational harbor on the River Salo is located close to the market square. In consequence, the variable measuring distance to the town center can also be considered to serve as a proxy for recreational benefits received from the river. In addition, river views are rare from the terraced house apartments because the river is narrow and the landscape flat.

Data on renovations of dwellings was not available. Therefore the age of a building serves as a proxy for the condition of the apartment in question. The age variable has been calculated in the following way: age of building = transaction year − construction year of building.

4. ESTIMATION RESULTS

To define the functional form of the hedonic equation, the following linear Box–Cox model was fitted to the data

$$P^{(\lambda)} = \alpha_0 + \sum_{i=1}^{3} \alpha_i Z_i^{(\lambda)} + \alpha_4 Z_4^{(\theta)} + \alpha_5 Z_5 + \sum_{j=1}^{3} \beta_j D_j + e, \qquad (2)$$

where P is real unencumbered selling price for the housing company unit in a terraced house. $P^{(\lambda)}$, $Z_i^{(\lambda)}$ ($i = 1, 2, 3$), and $Z_4^{(\theta)}$ are Box–Cox transformations as described in Sec. 2.

In hedonic price, Eq. (2), there are five quantitative explanatory variables, Z_i ($i = 1, 2, \ldots, 5$), measuring: floor area of the dwelling, distance to the center of Salo, distance to the local shopping center, distance to the nearest forested area, and age of the building. The variable Z_4, measuring distance to a forest park, is transformed by the separate transformation parameter, θ. The other transformation parameter, λ, is constrained to be the same across all other transformed

Transformed ($\lambda = 0.09$) dependent variable
Unencumbered real selling price for a dwelling in a terraced house

Transformed ($\lambda = 0.09$) explanatory variables	Estimated coefficient	Standard error	t-ratio
Floor area of the dwelling, m^2	1.604	0.0381	42.10
Distance to the center of Salo, km	−0.333	0.0563	−5.91
Distance to the local shopping center, km	−0.100	0.0289	−3.47
Transformed ($\theta = 0.57$) explanatory variable			
Distance to the nearest forested area (forest park), km	−0.116	0.0330	−3.51
Untransformed explanatory variables			
Age of the building, years	−0.044	0.0030	−14.68
Municipality			
0 = Salo	...	...	...
1 = Halikko	0.173	0.0630	2.75
Brick house			
0 = No	...	...	...
1 = Yes	0.209	0.0410	5.10
View to forest			
0 = No	...	...	...
1 = Yes	0.137	0.0439	3.12
Constant	14.321	0.2189	65.43

adj $R^2 = 0.87$ $n = 590$ $F_{9590} = 205\,906.27$ log likelihood $= -6830.43$

variables except Z_4. Furthermore, the variable Z_5, measuring the age of the building at the time of the transaction, is untransformed, because the sample included both new and old houses. Equation (2) has three qualitative explanatory variables, D_j ($j = 1, 2, 3$), indicating municipality, facade material and the possible forest view from the dwelling window. e is the stochastic error term. The variables included in the model (2) were selected on the basis of several estimation trials and information on the multicollinearity of the explanatory variables. Those variables that did not enter with statistically significant coefficients were omitted from the equation.

The results of maximum likelihood estimation are presented in Table II. The estimated Box–Cox regression is clearly statistically significant. The estimated value for the transformation parameter λ is 0.09 and the estimated value for the transformation parameter θ is 0.57. Those values are so close to zero that it is worth testing whether the log-linear functional form ($\lambda = \theta = 0$) is appropriate for the hedonic price equation. Hence, it is postulated that

$$H_0: \lambda = \theta = 0 \text{ vs. } H_1: \lambda \neq \theta \neq 0.$$

Since the value of the test statistic, 3.68, is smaller than the critical value, 5.99, the null hypothesis may be accepted at the 0.05 level.[1] Furthermore, it turns out that

[1] Under the null hypothesis, the likelihood ratio, $LR = 2[L_{max}(\lambda, \theta) - L_{max}(\lambda^*, \theta^*)]$, is asymptotically distributed as a χ^2 random variable with two degrees of freedom. Substituting the values of the unrestricted and restricted log likelihood functions in the likelihood ratio, the value of the test statistic LR is $2[-6830.43 - (-6832.27)] = 3.68$. Assuming $\alpha = 5$ percent, the upper percentage point of the χ^2 distribution with two degrees of freedom is 5.99.

according to the asymptotic likelihood ratio test statistic, also the functional form where $\lambda = 0$ and $\theta = 1$ may be accepted to the hedonic price equation at the 0.05 level. This is possible because the testing procedure is only partially nested [15]. In fact, either of those special cases could be accepted to the functional form for the hedonic price equation, but the special case where $\lambda = 0$ and $\theta = 1$ is slightly better according to the statistical criteria used.[2] Thus, we may next estimate a model where variables P and Z_i ($i = 1, 2, 3$) are linear in logarithms, and where the relation between the selling price and the variable Z_4 measuring distance to a forest park is semilogarithmic.

The hedonic equation to be estimated applying the method of ordinary least squares is

$$\ln P = \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln Z_i + \alpha_4 Z_4 + \alpha_5 Z_5 + \sum_{j=1}^{3} \beta_j D_j + e. \tag{3}$$

Multicollinearity among explanatory variables is detected once more. The variable related most to other explanatory variables is logarithmic distance to the center of Salo. The other explanatory variables explain 78 percent of the variation in the log of distance to the center of Salo.[3] Furthermore, due to expansion of housing, the coefficient of correlation between the variables logarithmic distance to the center of Salo and age of building is -0.60. Fortunately the variables measuring the urban forest amenities are not highly related to other explanatory variables. Naturally, the variables measuring distance to the nearest forested area and the forest view are related themselves. The average distance to the nearest forested area from dwellings with a view onto forest is only 30 meters, whereas from those dwellings that have no view overlooking a forest the average distance to the nearest forested area is 365 meters. This suggests that these variables measure different amenities and the use of both variables in the price equation is justified.

To detect spatial autocorrelation, the data was ordered in housing districts. The errors in the regression model (3) are not serially correlated.[4] But, according to the heteroscedasticity tests,[5] the error variance of model (3) is not homogenous. Therefore, a new equation where a heteroscedasticity-consistent covariance matrix

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[2] The value of the log likelihood function (-6832.20) when $\lambda = 0$ and $\theta = 1$ is greater than the resulting value of the log likelihood function (-6832.27) when $\lambda = \theta = 0$.

[3] The other values of R^2 in *auxiliary regressions* are $R^2_{\text{Age of the building}} = 0.66$; $R^2_{\text{Municipality}} = 0.62$; $R^2_{\ln(\text{distance to the local shopping center})} = 0.39$; $R^2_{\text{Brick house}} = 0.37$; $R^2_{\text{Distance to the nearest forested area}} = 0.25$; $R^2_{\text{View to forest}} = 0.22$ and $R^2_{\ln(\text{floor area of the dwelling})} = 0.21$.

[4] The *Runs test*, also known as the *Geary test*. H_0: Observed sequence of 590 residuals is random, i.e., no autocorrelation. H_1: Observed sequence of 590 residuals is not random, i.e., serial correlation. The number of runs is 248, and the number of positive (negative) residuals is 323 (267). Since the number of runs falls inside the 95 percent confidence interval (269.77, 316.91), we can conclude that there is no autocorrelation.

[5] *Glejser test*, where the absolute value of OLS regression residual is explained by all explanatory variables in the model (3). H_0: The error variance is homoscedastic vs H_1: Heteroscedasticity in the error variance. Since the value of the test statistics, 61.21, exceeds the critical value $\chi^2_{0.05}(8) = 15.51$, one can reject the null hypothesis. *Breusch–Bagan–Godfrey test*, where the squared OLS regression residuals are explained by all explanatory variables of the model (3). H_0: The error variance is homoscedastic vs H_1: Heteroscedasticity in the error variance. Since the value of the test statistic, 49.38, exceeds the critical value $\chi^2_{0.05}(8) = 15.51$, one can reject the null hypothesis, and conclude that there is heteroscedasticity in the error variance.

Hedonic Price Equation. Semilogarithmic Relationship between the
Dwelling Price and Distance to the Nearest Forested Area

Dependent variable
ln(unencumbered real selling price for a dwelling in a terraced house)

Explanatory variables	Estimated coefficient	Standard error	t-ratio
ln(floor area of the dwelling, m^2)	0.779	0.0201	38.71
ln(distance to the center of Salo, km)	−0.111	0.0228	−4.87
ln(distance to the local shopping center, km)	−0.033	0.0113	−2.96
Distance to the nearest forested area (forest park), km	−0.057	0.0171	−3.37
Age of the building, years	−0.015	0.0012	−12.32
Municipality			
0 = Salo	...	...	...
1 = Halikko	0.046	0.0206	2.24
Brick house			
0 = No	...	...	...
1 = Yes	0.068	0.0156	4.33
View to forest			
0 = No	...	...	...
1 = Yes	0.048	0.0143	3.37
Constant	9.082	0.0883	102.91

adj $R^2 = 0.87$ $n = 590$ $df = 581$ $F_{9581} = 544\,720.69$ Durbin–Watson = 1.91

was used in order to correct the estimates for an unknown form of heteroscedasticity was estimated [54]. The estimation results are given in Table III.

In the estimated regression model the independent variables explain about 87 percent of the variation in the log of real selling price. According to the results, the partial elasticity of dwelling price with respect to the floor area of the dwelling is about 0.78. Hence, holding the other characteristics of housing constant, a 1 percent increase in the floor area of a dwelling leads to the average of 0.78 percent increase in the selling price of the dwelling. Similarly, when the distance from the house to the center of Salo increases by 1 percent, the selling price decreases on the average by 0.11 percent.

Furthermore, the relation between dwelling price and age of the building is semilogarithmic. A 1 year increase in the age of the building leads to a 1.5 percent decrease in the selling price. Moreover, controlling the other characteristics of housing, the dwelling units in Halikko are, on average, 4.7 percent more expensive than in Salo. Houses made by brick are 7.0 percent more expensive than houses made by other construction materials (e.g., wood or concrete).

The model includes two variables measuring urban forest amenities. The first one is distance to a forest park. According to the estimation results, an increase of one kilometer in the distance to the nearest forested area leads to an average decrease of 5.9 percent in the market price of the dwelling. The relation between dwelling price and the distance to the nearest forested area is depicted in Fig. 1. The second variable is view onto forest. Dwellings with a view onto forest are on average 4.9 percent more expensive than dwellings with otherwise similar charac-

teristics.[6] According to the estimation results 95% confidence interval for the variable measuring distance to the nearest forested area is $(-0.091--0.024)$ and for the variable view onto forest $(0.020-0.076)$.

As discussed earlier, according to the asymptotic likelihood ratio test statistics, logarithmic transformation of the park distance was also acceptable. Thus, both forms of relationship between dwelling price and park distance, the semilogarithmic and the log-linear, are presented in Fig. 1.

Also a model where the distance to a forested park was classified using dummy variables was estimated. The dummy variables describing proximity of a forested park were constructed so that the comparison level was the distance of between 1.0 and 1.5 km. According to the estimation results reported in Table IV, distances up to 600 meters have a significant positive effect on the price of dwellings. If the distance is more than 600 meters the effect on price is not statistically significant at 5 percent level. As expected, the effect of distance on price decreased when distance increases (Fig. 2).

Until now, we have assumed that the hedonic equation is stable with respect to time during the estimation period 1984–1986. To test the temporal stability of the estimated parameters, the years 1985 and 1986 were distinguished from the year 1984 using two dummy variables, D85 and D86. The estimation results suggest that the aggregation of data from the different time periods was generally justified. Apparently because of sampling fluctuations, the partial elasticity of real selling price in 1984 with respect to distance to the nearest forested area does not differ statistically significantly from zero. In 1985 and 1986 the relationship between the selling price of dwellings and distance to the nearest forested area is clearly negative. Furthermore, the price ratios between Salo and Halikko and between the brick houses and the other houses have not been stable during the period 1984–1986.

5. DISCUSSION

Urban development projects may cause negative externalities, loss of amenity values of green spaces, which should be taken into consideration in planning. One of the key questions is whether the provision of green areas is in balance with the residents' expectations and also willingness to pay for the areas. In many countries urban forests are in a continuous process of fragmentation under the pressures of other land-uses. Most municipalities, however, do not have any specified urban forest policy [21, 27]. In consequence, new means are needed in planning of assessing the losses and gains to the quality of urban environments.

The aim of this study was to measure urban forest benefits in monetary terms. The results clearly show that residents pay for such environmental amenities as the forest view through property prices. On the housing market of Salo, buyers have to pay 4.9 percent more to obtain a dwelling with a forest view. In addition, proximity to the nearest forested park was found to have a significant positive effect on house prices. According to the semilogarithmic model, an increase of one kilome-

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[6]The percentage change of an urban forest amenity is calculated by taking the antilog (to base e) of the estimated coefficient, from which one is subtracted. In the case of the first variable, the antilog of the estimated coefficient, 0.057 469, is 1.059 152. Thus the relative change is (1.059 152 − 1 = 0.059 152), or 5.9 percent. In the case of the second variable, the antilog of the estimated dummy coefficient, 0.048 274, is 0.049 458. Therefore the relative change is 4.9 percent.
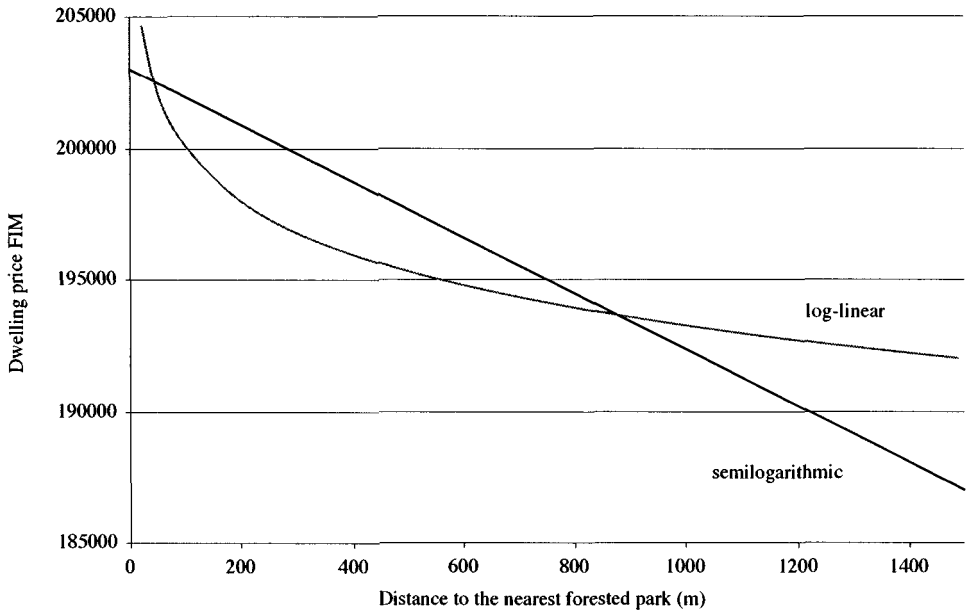
FIG. 1. Effect of distance to the nearest forested area on dwelling price. Both semilogarithmic and log-linear relationship between the dwelling price and the independent variable. The model was corrected by adding a correction factor equal to $e^{1+(\delta^2/2)}$ to the equation [25].

TABLE IV

Hedonic Price Equation. The Use of Dummy Variables Measuring
Distance to the Nearest Forested Area

Dependent variable
ln(unencumbered real selling price for a dwelling in a terraced house)

Explanatory variables	Estimated coefficient	Standard error	t-ratio
ln(floor area of the dwelling, m^2)	0.781	0.0202	38.58
ln(distance to the center of Salo, km)	−0.106	0.0222	−4.76
ln(distance to the local shopping center, km)	−0.035	0.0118	−2.96
Age of the building, years	−0.015	0.0012	−12.43
Municipality			
0 = Salo	…	…	…
1 = Halikko	0.043	0.0207	2.09
Brick house			
0 = No	…	…	…
1 = Yes	0.069	0.0154	4.46
View to forest			
0 = No	…	…	…
1 = Yes	0.042	0.0182	2.29
Distance to the nearest forested area (forest park)			
1 km or more (base category)	…	…	…
0.005–0.099 km	0.073	0.0199	3.67
0.100–0.299 km	0.057	0.0225	2.54
0.300–0.599 km	0.046	0.0233	1.99
0.600–0.999 km	0.041	0.0228	1.80
Constant	9.001	0.0878	102.56

adj $R^2 = 0.87$ $n = 590$ $df = 581$ $F_{9581} = 406\,823.65$ Durbin–Watson = 1.90
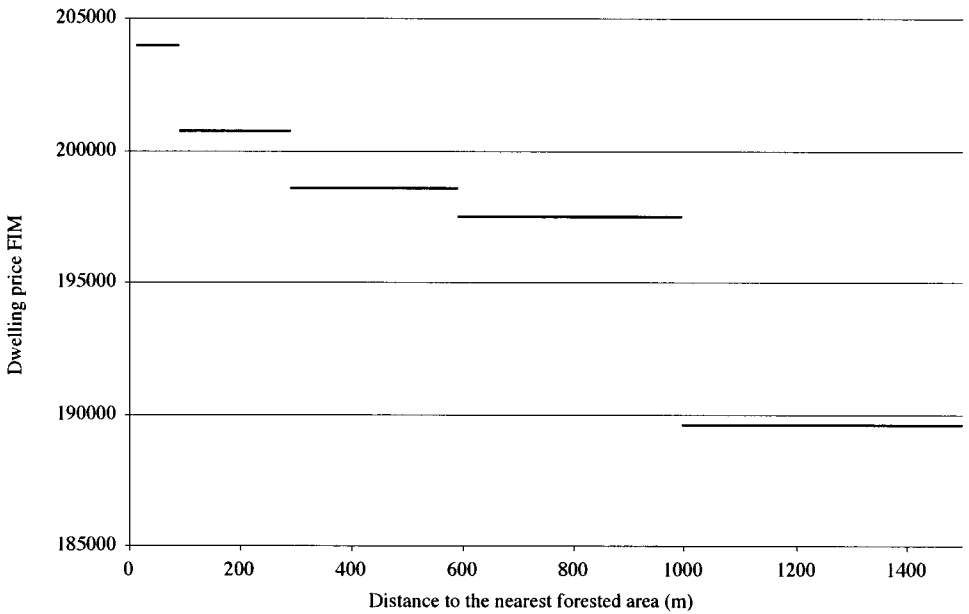
FIG. 2. Effect of distance to the nearest forested area (as the qualitative variable) on dwelling price.

ter in the distance reduced the price of a dwelling by 5.9 percent. However, when the relationship between the dwelling price and distance to the nearest forested area was log-linear, or the distance was established using dummy variables, the effect to selling prices was strongest up to a distance of 300 meters. The results suggest that distance to a forested park has a price effect if the area is within walking distance from home. This is in line with urban recreational studies, which also report that the most intensive use of such areas occurs near the home environment (cf. [13, 18, 44]).

In contrast to the findings of a previous study conducted in Joensuu, larger recreational areas did not have a significant impact on apartment prices in this study. The result is explained by the differences in the supply of recreational areas in the two towns under study. Proximity to a recreational area may not have been as relevant a variable in Salo as in Joensuu, since by the mid-1980s the recreational opportunities in Salo were rather poor—there were only two rather small recreational areas in the town. In Joensuu, in contrast, there were several larger wooded recreational areas with facilities within the town limits [50].

Moreover, selecting the proper variables describing urban forest benefits is problematic. At present, information on the values that residents attach to forests remains insufficient and the urban forests benefits are difficult to classify and measure quantitatively. Compromises have to be made between the multiple benefits of urban forests, the number of variables, and their measurability. As the environmental variables are often correlated themselves, the researcher has to choose those variables thought to measure different benefits. In some cases this is difficult, since many forested areas produce multiple benefits such as pollution

control, screening, and aesthetic attractions. In the present study, views and distances are suggested as descriptions of different benefits received from urban forests, although it is difficult to avoid overlapping completely.

Previous studies of the economic value of urban forests also report on significant positive effects on house prices, but they have focused on individual trees and thus make comparisons difficult (cf. [1, 33, 34]). To some extent the significant variables in the model also differ from those used in the study conducted in Joensuu [49]. Besides to difference in the geographical location of Salo and Joensuu, this is probably due to the local features of the housing markets, since cultural distinctions and architectural valuation attached to housing may differ between regions. For example, in contrast to the findings in the Joensuu study, roof-type did not seem to have an effect on property prices in the district of Salo. In spite of local differences between the towns, the results of this study provide a good gauge of valuations of urban forests in Finnish towns. In central Europe, however, landscape preferences and demands for urban greens probably differ as a result of cultural differences and the local history of land use.

It is also suggested that the monetary values calculated for green spaces represent the lower limit of the monetary value of the particular areas since the method captures only the values attached to housing. Excluded are, for example, non-use values such as the value of urban biodiversity as well as the recreational benefits experienced by tourists or other visitors not living in the area. Furthermore, HPM measures only the valuations made by people who can afford to pay for the amenities. It also has to be noted that explanatory variables may reflect features of housing that are different from what they explicitly purport to measure, e.g., the distance to the town center in the case of Salo also encompasses benefits accruing from the proximity of water, the age of buildings functions as a proxy for the historical value and the condition of dwellings, and so on.

The present study has been conducted on the basis of data assembled in the mid-1980s. However, considering whether the valuations have changed since then would also be a relevant issue. Recent debates and increased urban forest conflicts suggest that their importance has increased rather than decreased during the past decade (cf. [5, 12, 17, 20]). Therefore, it is suggested that the relative importance of urban forests as an environmental quality indicator is at least the same today as in the mid-1980s.

Collecting data for this study was time-consuming, but in future data on house prices will be more readily available from price registers. Moreover, recent innovations in GIS and computer technology with numerical town maps are facilitating the automatization of measurements for this kind of study. Many communities in Finland are making digital inventories of their green space structure, which considerably eases the collation of precise information on urban greens with respect to housing.

The main use of the method and models developed is the economic valuation of urban plans, where the costs of, for instance, allocating housing stock are compared. Generally this evaluation includes the establishment and operational costs of new housing areas and subsumes both public and private costs. The choices are often either to allocate new dwellings to existing green areas near a town center or to establish a new residential area on an urban fringe. The former alternative causes negative externalities for those living near green areas as losses of green space benefits, which in their turn should be included in the assessment procedure.

In the latter alternative, the concomitant increases in (private) transportation costs are included in the calculation.

It must also be added that the quality of environment in several residential areas built particularly in the 1970s is poor (cf. [12, 14]). Public awareness that establishment of a new green area raises prices of dwellings in the residential area helps in justifying greening projects. The hedonic models may also serve as a tool for argument in a court of law when monetary compensation due to declining of the quality of the residential environment is considered. This kind of situation may happen, for example, when a buyer has bought a dwelling with a view onto forest, which is subsequently converted to another use.

The use of the hedonic price models is illustrated by calculating the monetary value of a hypothetical forest park using the estimated semilogarithmic model (Table III, Fig. 1). It is assumed that size of the forest park is 1 hectare and it is circular. First we find out the total value of the forest views and at the second stage attention will be paid to the effect of the distance to the forest park. To shift valuation closer to the present, temporal stability of the hedonic equation is assumed.

According to the estimation results, residents in the housing market of Salo pay 4.9 percent more for a dwelling with a forest view. The circumference of the park area is 354.5 meters ($= 2\pi\sqrt{10,000/\pi}$ meters). Given that the average yard size is four hundred square meters (10 m × 40 m), the number of dwellings next to the park is 35. The total value of the apartments next to the park is found by multiplying the number of homes, 35, with the average size of an apartment in a terraced house, 90 sq.m, and with the average unit price of a dwelling. In 1996, the average unit price of an apartment in a terraced house in Salo was 4225 FIM per square meter (Statistic Finland). Calculated in this way, the total value of 35 apartments is approximately 13.31 million FIM, and the value of the forest view is 4.9 percent of the total value of dwellings, which is 652 000 FIM (110 000 ECU).

Moreover, according to the semilogarithmic model an increase in distance of 1 kilometer reduced the average price of a dwelling by 5.9 percent. It is assumed that the price effect is zero at 1 kilometer distance. Furthermore, the price effect is calculated only up to 600 meters, because it is a relevant assumption in a case of a small park. The size of the housing area influenced by the park is 1.344 km² (πr^2, $r = 0.6$ km). The total surface of constructions in the area is calculated by multiplying the size of the housing area (1.344 km²) with typical construction efficiency (0.1) in small-house residential areas in Salo. The received figure (134 400 m²) is multiplied with relative amount of living area in a construction (0.8) to calculate the total floor surface of apartments, which is 107 520 m². Now, the total value of apartments the housing area is 454.27 million FIM, which is calculated by multiplying the total surface of the apartments 107 520 m² with their average price per square meter, 4225 FIM/m².

The aggregate price effect of the park across the housing area can theoretically be calculated using the general formula for the volume of the solid of revolution:

$$V = \int_a^b \pi [f(x)]^2 \, dx. \tag{4}$$

However, although the form of dependency between dwelling price and the distance to a park is not linear, Fig. 1 illustrates that their relationship is close to
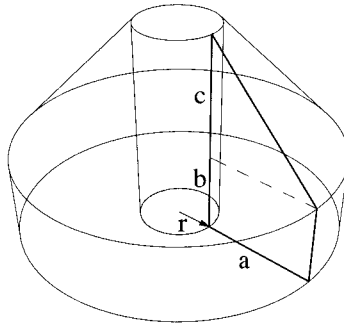
FIG. 3. The price effect across housing area can be calculated using the formula for the volume of solid of revolution $2\pi(r + \frac{a}{3})\frac{ac}{2} + 2\pi(r + \frac{a}{2})ab$, where $r = 0.056$ km, $a = 0.6$ km, $b = 2.36\%$, $c = 3.54\%$, and $b + c = 5.9\%$.

linear between 0–1000 meters. Therefore, the aggregate value of the park reflected to dwelling prices can be calculated geometrically using Guldin's law (1577–1643), i.e., the volume of the solid of revolution equals the area of the object times the distance travelled by its center of gravity (Fig. 3). Calculated this way, the value of the park is 4.88% from the total value of apartments, which is 22.17 million FIM. When the value of the view is added to this figure, the total value of the park is 22.82 million FIM (3.84 million ECU). If conversion of the park into other use is considered this value should be compared to increased costs when providing the building sites somewhere else.

The value of park capitalized in property prices can be calculated similarly using any other price model. In this example it was assumed that the park was the only one influencing the apartment prices within 600 meters, which applies in situations where parks are few. In practice different type of green areas may influence apartment prices, which should be also taken into consideration in calculations. If the construction efficiencies are higher (0.3–0.4), i.e., there would be mostly blocks of flats instead of small houses in the area, the estimated value of the park would also be considerably higher, approximately 66–89 million FIM. Here it should be stressed that social and ecological carrying capacity of the green area is limited. After a certain limit the high use of the park becomes also a nuisance for the nearby habitants, which may decrease property values.

ACKNOWLEDGMENTS

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